Keith M. Slauson[1] and **William J. Zielinski**, USDA Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, California 95521

Characteristics of Summer and Fall Diurnal Resting Habitat Used by American Martens in Coastal Northwestern California

Abstract

American martens use resting habitat between periods of activity to provide both thermal refugia and protection from predators. Maintenance or restoration of key elements of marten resting habitat, such as resting structures, requires that managers recognize their characteristics to protect them, or manage for their creation. We measured resting habitat at 4 scales: (1) the resting location—where the marten actually rested; (2) the resting structure—the habitat element that contained the resting location; (3) the resting site—characteristics in the immediate vicinity of each resting structure; and (4) the resting stand—the forest stand containing the resting structure. During the summer and fall of 2001 and 2002 we identified resting structures used by 12 radio-collared martens (7 Male, 5 Female) and 1 uncollared marten. The animals were the members of the only remnant population of martens within the historical range of the Humboldt marten (*M. a. humboldtensis*). The study area included portions of the Six Rivers National Forest, Smith River National Recreation Area, and adjacent Green Diamond Resource Company lands in coastal northwestern California. We located martens resting on 55 occasions in the following types of structures: snags (37%), logs (23%), live-trees (17%), slash-piles (10%), rock-piles (8%), and shrub clumps (6%). The location in the structure where the marten actually rested was determined on 92% of occasions and included chambers (33%), cavities (33%), broken tops (22%), branch platforms (6%), ground sites (6%), and basal hollows (2%). Woody structures were large, with mean dbh of 93.9 cm for live-trees , 94.9 cm for snags, and 88.2 cm maximum-diameter for logs. The mean age of 24 of the woody resting structures was 339 years (range 131–666 years). Our results are consistent with results from other studies on resting structure use and highlight the importance of large live and dead woody structures for American martens in coastal forests of northwestern California.

Introduction

Resting habitat is used daily between bouts of activity to provide thermoregulatory benefits and protection from predators and represents a key component of suitable habitat for American martens (*Martes americana*). We distinguished 4 components of resting habitat: (1) the *resting location*—the actual place (e.g., cavity, platform) in the resting structure where the marten rests (2) the *resting structure*—the habitat element (e.g., snag, log) in which the marten rests (3) the *resting site*—the characteristics of the area in the immediate vicinity of a resting structure and (4) the *resting stand*—the forest stand containing the resting structure (Figure 1).

Selection of particular types of resting locations and structures changes with seasonal and daily weather conditions as martens seek to maximize their energetic savings by selecting the microenvironment that offers the most thermal benefits (Taylor and Buskirk 1994). Although their long, thin shape confers benefits in search for prey, it results in high energetic costs for thermoregulation (Scholander et al. 1950, Brown and Lasiewski 1972). Because of their limited ability to store energy reserves (Buskirk and Harlow 1989), martens use behaviors that help conserve energy.

One behavioral trait is the selection of secure resting locations. These include live or dead trees (snags, stumps, logs), mistletoe clumps, witch's brooms, root cavities, root clumps, logging slash piles, rock piles, squirrel middens, squirrel grass nests, burrows, and shrubs (Martin 1987, Gilbert et al. 1997, Raphael and Jones 1997, Schumacher 1999). The types of structures used for resting varies both by region and by season (Shumacher 1999). However, 16 studies reviewed by Shumacher (1999) showed live trees, snags, and logs were used as resting structures 52% of the time during winter and 66% during the summer. In general, martens use more ground-based resting locations during the winter and more elevated sites during the summer. Furthermore, the majority of studies show that martens select the largest diameter live and dead woody structures available in their respective study regions (Wilbert 1992, Gilbert et al. 1997, Raphael and Jones 1997).

Populations of martens in coastal Oregon and California have declined and are currently

[1]Author to whom correspondence should be addressed:
E-mail: kslauson@fs.fed.us

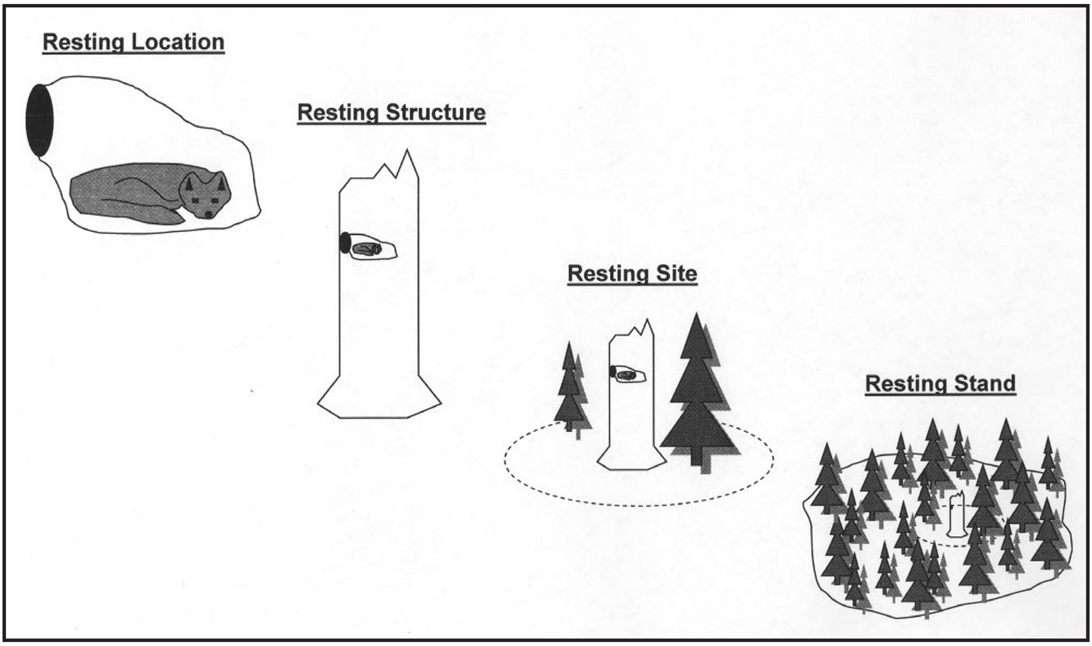

Figure 1. Four spatial scales of resting habitat for American martens.

known from only two disjunct regions in Oregon, and from a single population occupying an area representing <5% of the historical range of the Humboldt marten (*M. a. humboldtensis*) in California (Zielinski et al. 2001, Slauson 2003). Slauson et al. (2007) studied habitat selection and found Humboldt martens to select conifer-dominated stands with dense, spatially extensive shrub cover in the oldest developmental stage. At the home-range scale, martens selected the largest available patches of old-growth, old-growth and late-mature, or serpentine habitat. Old growth dominated areas selected by martens contained abundant large diameter live and dead woody structures and dense tree canopies. Serpentine habitats included a mix of developmental stages, dominated by small to medium diameter trees, sparse tree canopies, abundant large rocky features (e.g., fractured outcrops, rock piles) and dense shrub layers (Jimerson et al. 1995, Slauson 2003). Thus, we understand habitat selected by coastal martens at the stand and home range scales, but we have had no information about characteristics of their resting habitat. This is a major knowledge gap, particularly because martens appear to be more selective for habitat at the micro-scale (e.g., selection of denning and resting structures) than at other scales (Minta et al. 1999). The objective of this paper is to describe the characteristics of resting habitat used by the only remnant population of *M. a. humboldtensis* remaining in the coastal forests of northwestern California (Zielinski et al. 2001, Slauson 2003). This study represents the first description of resting habitat for martens within their range in the coastal forests of either California or Oregon.

Study Area

The 100 km^2 study area is located in southern Del Norte and northern Humboldt counties in coastal Northwestern California (41°30′00″N, 123°45′00″W) (Figure 2). It occupies portions of the Klamath-Siskiyou and Northern California Coastal Forest ecoregions (Ricketts et al. 1999). The study area ranges between 500 m to 1300 m in elevation and is located 10 to 30 km from the ocean. The climate is an inland expression of the maritime regime, characterized by moderate temperatures, distinct wet and dry periods throughout the year, and high rainfall during the winter months. Precipitation comes largely as rainfall, totaling between 200 and 300 cm annually. It rains >0.3 cm during an average of 96 days/year (Western Regional Climate Center 2006), suggesting martens may need to seek shelter from wet and

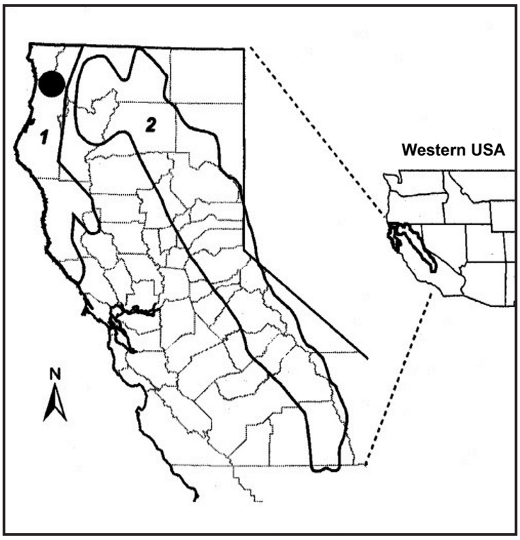

Figure 2. Historical ranges of the American marten in California, representing two subspecies: 1. *M. a. humboldtensis* and 2. *M. a. sierrae*. The location of the study area is indicated by the solid dot in extreme northwestern California.

cold conditions a significant portion of the year. Snowfall occurs sporadically and rarely persists below 900 m elevation. Fog is present within the western edge of the study area and further interior along major stream drainages, providing a source of moisture during the summer when there is typically very little rain.

The combination of moderate temperatures, high annual precipitation, and summer fog supports dense and continuous tree cover throughout most of the study area and dense shrub cover in mesic sites. Douglas-fir (*Psuedotsuga menziesii*) and tanoak (*Lithocarpus densiflora*) forest types dominate the study area, with redwood (*Sequoia sempervirens*) types becoming more prevalent on the western edge. Additionally, the presence of serpentine soil types fosters several structurally and compositionally unique forest types in the study area, which also harbor a rich diversity of plant species (Kruckeberg 1984). In these soil types, low levels of essential nutrients and high concentrations of detrimental elements offer a harsh growing environment for plants (Jenny 1980), resulting in open and rocky sites with slow growing woody plants and stunted trees (Jimerson et al. 1995).

Ninety-five percent of the study area is managed by the U.S. Forest Service (USFS), including portions of the Smith River National Recreation Area and Six Rivers National Forest. The remainder is owned and managed primarily for production of wood products by the Green Diamond Resource Company (GDRC).

The study area is also occupied by several other carnivore species that can compete with, or prey on, martens including gray fox (*Urocyon cinoreaorgenteus*), fisher (*M. pennanti*), bobcats (*Felis rufus*) and great horned owls (*Bubo virginianus*).

Methods

Animal Capture and Handling

We captured martens in two structurally distinct forest habitats where they had been previously detected at track plate stations (Slauson et al. 2007). One area was dominated by old growth and late-developmental stands of Douglas-fir forest types (hereafter non-serpentine habitats) and the second area was dominated by serpentine forest communities (hereafter, serpentine habitats). We captured martens in serpentine and non-serpentine habitats in order to study the characteristics of resting habitat across the variation in forest structure and composition used by this population.

We used Tomahawk live-traps (Model 205, 22.8 x 22.8 x 66 cm, Tomahawk Live Trap Company, Tomahawk, Wisconsin), modified with two pieces of masonite covering the wire mesh floor, to discouraging digging and reduce toe injury, and a wooden cubby box attached to the end for shelter (Wilbert 1992). We baited each trap with chicken and a commercial scent lure (Gusto, Minnesota Trapline Products, Pennock, Minnesota) and checked each trap at least once daily.

We restrained martens in a metal handling cone and sedated them with an intra-muscular injection of ketamine hydrochloride and Diazepam mixture (10 mL ketamine/5 mL Diazepam); animals typically received 0.10 to 0.15 mL/kg body mass. Once immobilized, animals were sexed, measured, weighed, ear-tagged, and photographed. Martens were fitted with VHF radio collars (Model BT; AVM Instrument Company, Ltd., Colfax, California), weighing 20-23 g (<4% of body weight) that transmitted 3 types of signals: active, inactive and mortality.

Determining Resting Locations

Resting locations were sought by homing on the radio signals from animals that were inactive (determined by several minutes of continuously inactive radio signals). Considerable care was taken to not disturb the animal once it was located or was nearby. When the resting structure was identified, we attempted to determine the exact location of the animal in the structure, the site was flagged and the UTM coordinates collected using a GPS unit. Each resting site was re-visited when the structure was unoccupied to conduct detailed vegetation sampling.

Habitat Sampling

Resting Locations—We categorized 6 types of resting locations: cavities, chambers, broken tops, branch platforms, ground sites, and basal hollows. We distinguished cavities and chambers because of differences in how they are created (Table 1). We measured the height to the resting location, diameter of the resting location entrance, and diameter of the structure at the resting site.

Resting Structures—We categorized 6 types of resting structures: live trees, snags, downed logs, slash piles, rock piles, and shrub clumps. For live trees or snags, we recorded the species, diameter at breast height (dbh), height of structure, and condition class (1-7; Maser et al. 1979). For logs, we recorded the species, minimum and maximum diameter, length, and condition class (1-5; Maser et al. 1979). We estimated the ages of live trees, snags, and logs by counting annual growth rings from cores taken near the base (trees, snags) and at the maximum diameter (logs). For slash or rock piles, we measured the maximum pile diameter, height, and diameters of the 5 largest elements. Because we did not observe logs with cavities in slash piles, all resting locations in logs were assumed to be chambers. For shrub clumps, we recorded the species, maximum clump diameter, height, and the age of the dominant stem was estimated by counting the annual rings from a basal cross section.

Resting Sites—For all resting structures we recorded the following features of the resting site: percent slope, macro aspect (direction of the dominant slope of the site), distance to water, distance to logged area (e.g., clearcut or thinned stand), and developmental stage (Jimerson et al. 1996). Percent slope was determined using a clinometer and macro aspect using a compass. Distance to water was determined through map interpretation and distance to clear-cut (0, 1-50, 51-100, >100 m categories) area was visually estimated in the field. Two perpendicular 25 m transects were established, centered on the rest structure, to estimate the percent shrub and rock

TABLE 1. Definitions for resting locations and the structures that support them used by American martens in northwestern California during the summer and fall seasons of 2001 and 2002.

Resting Location	Applicable Resting Structures	Resting Location Definition
Chamber	Snag, log, slash pile	Chambers are created by elements (e.g., snags, shrub growth, logs) falling or against each other (e.g., rocks, logs) such that suitable interstitial spaces are created.
Cavity	Snag, log, live tree	Cavities are created by heart-rot decay and the excavation of nesting holes by woodpeckers (pileated woodpecker, *Dryocopus pileatus*, northern flicker, *Colaptes auratus*).
Broken top	Snag, live tree	Platform-like feature created by the breakage of the snag or tree bole.
Branch platform	Live tree	Large diameter branch, complex branching, or epicormic branching forming a suitable platform.
Ground	Shrub clump	Location on the ground typically with cover features (e.g., shrubs, logs, rocks) closely associated.
Basal hollow	Live tree	Cavity-like feature at the base of a tree bole created by the individual or synergistic action of fire and decay.

cover (line-intercept, percent of line coverage) and to estimate the density of downed logs >30 cm maximum diameter (strip transects, 25 m x 10 m). The dbh and decay class of all snags within a 25 m radius of the rest structure were recorded. Basal area was measured using a 20-factor prism sweep, centered on the resting structure. For each tree selected by the prism sweep, species, dbh, and condition class was recorded. Canopy closure was estimated using the mean estimate from spherical densiotometer measurements taken in each of the four cardinal directions, at the plot center and at the ends of each 25 m transect.

Resting Stands—The developmental stages for each stand were derived from a vegetation coverage developed by the Six Rivers National Forest Ecology Program (EP) (Jimerson et al. 1996). The EP vegetation layer has a classification error of <10% (John Hunter, U.S. Fish and Wildlife Service, unpublished data) and was developed through a combination of plot data, air photo interpretation, polygon typing based on the classification system, and ground truthing. To determine the composition of developmental stages available for martens to use for resting, we buffered the outermost resting locations by 500m (approximately ½ the average diameter of a marten home range) in a GIS and determined the proportions of stands available in each developmental stage. Selection of stand developmental stages was evaluated using a chi-square test.

Results

Locating Resting Martens

Attempts to locate martens while resting failed on approximately 75% of attempts, due largely to the difficulty in making a quiet approach through dense shrub layers. Thirteen martens (7 Male:5 Female:1 sex unknown) were successfully found at resting locations on 55 occasions, which included 52 unique structures (re-use of structures = 5.4%), from 23 August to 18 November 2001 and 29 June to 26 November 2002. The number of unique resting structures used by each gender was nearly equal (28 Male:23 Female). The actual resting location was determined on 92% of occasions, based on visual observation of the marten in or exiting the resting location. Seventy-seven percent of resting structures were located in non-serpentine habitats and 23% in serpentine habitats. The great majority of rest structures were located on USFS lands (94%).

We were unable to continue monitoring martens into the winter due to premature radio collar failure. Radio collars remained functional for an average of 3.4 months (range 0.5 to 6); all failed prior to their expected battery life. All resting martens were found during daylight periods, between 0950 and 1845 (median = 1450).

Resting Locations

Martens used cavities, chambers, and broken snag tops for the majority (87%) of their resting locations (Figure 3). Branch platforms, ground sites, and basal hollows collectively represented 13% of resting locations (Figure 3). On the five occasions when martens were found resting during rainfall, they were in either cavities or chambers. Resting locations in snags or trees were typically >10m from the ground where dbh averaged >70 cm (Table 2).

Resting Structures

Of the 52 unique resting structures, the majority (77%) were in snags, logs, or live trees (Table 3). However, in serpentine habitats these structures accounted for only 58% of rest structures, compared to 83% in non-serpentine habitats. Most rest

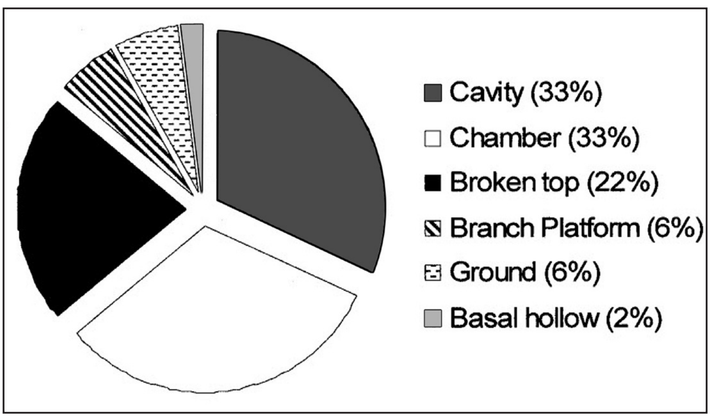

Figure 3. The types of diurnal resting locations (n =52) used by American martens in coastal northwestern California during the summer and fall of 2001-2002.

TABLE 2. Characteristics of diurnal resting locations in woody structures used by American martens in coastal northwestern California. SEs are listed in parentheses.

Location Type	n	Diameter (cm) at Rest Site	Entrance Height (m)	Entrance Width (cm)
Cavity	15	75 (8.4)	14 (2.5)	29 (12.2)
Chamber	13	70 (8.4)	-----	29 (6.7)
Platform	9	78 (10.7)	15 (3.1)	

structures were conifers (87%), with 13% occurring in chinquapin (*Chrysolepus chrysifolia*).

Large snags were the most frequently used structure type (Table 3), with mean dbh for conifer and hardwood snags of ≥ 93 cm and 50 cm, respectively (Table 3). Snags were typically >10 m in height and the height to the cavities used in snags was often >5 m (Table 3). The mean age at death of 14 snags was 403 years (SE = 28, range 262-666). Cavities used by marten were created by heart rot and decay (n = 7), but also by woodpeckers (n = 3).

Twelve resting structures were downed conifer logs with mean maximum diameter of >75 cm (Table 3). The mean age at death of 5 logs was 406 years (SE = 80, range 254-660). Nine resting structures were in live trees, where martens used branch platforms and broken tops, cavities, and basal hollows. The mean diameter of live conifers was 93.9 cm and live hardwoods was 92.8 cm (Table 3). We estimated the age on 1 live conifer tree to be 176 years.

All slash piles were used by a single male, and occurred on the margins of small (<5 ha) clearcuts. Slash piles used were large and composed of some large (>60 cm maximum diameter) logs (Table 3). Four resting structures were rock piles, in which all resting sites used were chambers. This resting structure type was the most difficult to verify and we suspect it is under-sampled in the serpentine area. On 10 occasions in serpentine habitats we were <50 m from martens that became active and left their resting locations. Searches of the immediate area resulted in no potential live or dead wood resting structures, only one or more rock piles with likely suitable chambers.

Resting Sites

The majority of resting sites were north facing macro aspects and on moderate slopes (Table 4). Seventy-four percent of resting sites were >100 m from surface water and 65% were >100 m from logged areas. The 8 rest sites in logged areas all were in small <1-2 ha patch clear cuts or selection cuts. Tree canopy closure averaged 76%, but was higher in non-serpentine than serpentine sites (Table 4). Shrub cover was uniformly dense across all sites, while rock cover was only common in serpentine sites (Table 4). Dead woody structures (snags and logs) of sufficient size (>30 cm diameter) to potentially serve as resting structures were abundant in the vicinity of resting structures (Table 4). The mean (SE) dbh of snags and live trees in the vicinity of resting structures was 87 cm (4.1) for conifer snags, 87 cm (3.6) for live Douglas-fir, 87 cm (8.9) for live sugar pine, and 32 cm (2.6) for live chinquapin.

Resting Stands

Overall, the majority of resting stands were in the oldest developmental stages: old growth and late-mature (Figure 4). The pattern of use of stand developmental stages by martens differed significantly from availability ($\chi^2 = 61.6$, df = 5, $P < 0.0001$). Martens showed highly disproportionate use of old growth stands compared to their availability, suggesting selection for this developmental stage, while showing neutral or negative selection for most earlier developmental stages (Figure 4). The majority of resting structures (77%) occurred in the non-serpentine forests that were characterized by late-successional conifer-dominated stands. Ninety-five percent of the resting structures in non-serpentine habitats were in woody structures compared to 58% in the serpentine habitats. Rock and shrub clumps represented nearly half (42%) of resting structures in the serpentine habitats and were in earlier developmental stages (shrub through mid-mature, Figure 4).

Den Structures

One adult female (F07) was observed with a single kit at 3 structures, confirming these sites as maternal dens. The first was located in mid June in the broken top of a live chinquapin (dbh = 66 cm, height = 13.8 m). The second den site was located in July in the broken top of a Douglas-fir (dbh = 113 cm, height = 24.7 m). The third was found in July in a cavity of a Douglas-fir snag (dbh = 115, height = 15.1 m, condition class = 6).

TABLE 3. Characteristics of diurnal resting structures and resting locations used by American martens in northwestern California during the summer and fall seasons of 2001 and 2002.

Rest Structure Type (n, % total n)	Rest Location Type (n)	Species (n)	Mean DBH (snags, trees) Max. Diameter (logs; cm)	Mean DBH/ Max. Diameter Ranges	Height m (SE)	Condition Class*	Length m (SE)	Mean Max. Pile Diam. (SE)	Mean Diameter of 5 Largest Elements (SE)
Snag (19, 37%)	Cavity (11)	Conifer (9)	95	67-140	16 (5.1)	4 to 7	---	---	---
		Hardwood (2)	50	41-50	11	6	---	---	---
	Broken top (8)	Conifer (8)	93	70-124	10 (1.6)	6 to 7	---	---	---
Log (12, 23%)	Cavity (4)	Conifer (4)	76	44-114	---	3 to 4	12 (1.1)	---	---
	Chamber (8)	Conifer (8)	94	50-122	---	3	14 (1.5)	---	---
Live Tree (9,17%)	Cavity (2)	Conifer (1)	95	57-165	36	1 to 2	---	---	---
		Hardwood (1)	114	---	20	2	---	---	---
	Broken Top (3)	Conifer (1)	113	---	25	2	---	---	---
		Hardwood (2)	62	57-66	15 (0.8)	1 to 2	---	---	---
	Branch Platform (3)	Conifer (3)	82	61-102	22 (2.5)	1	---	---	---
	Basal Hollow (1)	Conifer (1)	74	---	19	2	---	---	---
Slash Pile (5, 10%)	Chamber (5)	---	---	---	2 (0.4)	---	---	17 (1.7)	60 (3.6)
Rock Pile (4, 8%)	Chamber (4)	---	---	---	1 (0.3)	---	---	4 (0.8)	97 (22.7)
Shrub Clump (3, 6%)	Ground (3)	VAOV (1)**	---	---	1	---	---	4	---
		LIDEE (2)**	---	---	2 (0.0)	---	---	2 (0.0)	---

*Condition classes following the classification methods of Maser et al. (1979).

**VAOV = *Vaccinium ovatum*, LIDEE = *Lithocarpus densiflora echinoides*.

TABLE 4. Characteristics of 52 diurnal resting sites used by American martens in coastal northwestern California. SEs are in parentheses.

	n	Percent Slope	Macro Aspect NW	NE	SW	SE	Percent Cover Canopy	Shrub	Rock	Basal Area	Snags/Ha >30 cm	Logs/Ha >30 cm
Serpentine	12	35% (4.9)	17%	58%	8%	17%	61% (7.3)	87% (5.9)	25% (6.7)	68 (11.9)	63 (31.2)	42 (13.0)
Non-serpentine	40	42% (3.4)	38%	35%	26%	0%	83% (4.2)	87% (2.2)	2% (1.5)	188 (15.2)	58 (11.7)	81 (15.8)
Combined	52	40% (2.8)	33%	41%	22%	4%	76% (3.9)	87% (2.2)	8% (2.5)	154 (14.2)	59 (10.4)	71 (12.3)

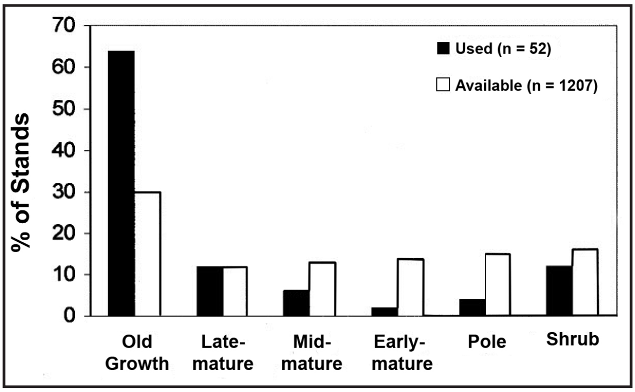

Figure 4. Developmental stages of stands used by American martens for diurnal resting versus their availability in coastal northwestern California during the summer and fall of 2001-2002. Serpentine and non-serpentine stands are combined; for descriptions of developmental stages see Jimerson et al. (1996). The pattern of use of stand developmental stages by martens differed significantly from availability ($\chi 2 = 61.6$, df = 5, $P < 0.0001$).

Discussion

Martens in coastal northwestern California used enclosed and/or elevated resting locations (cavities, chambers, broken top platforms) in large woody structures for the majority of their diurnal resting events during the late summer and fall. The frequent use of woody structures is consistent with Schumacher's (1999) review of resting structure use in North America during the summer-fall period. Although we did not conduct formal selection analyses on the size distribution of structures available in the study area, martens typically rested in the largest size classes of trees and snags available in the study area, consistent with results from elsewhere (e.g., Wilbert 1992, Gilbert et al. 1997, Raphael and Jones 1997).

Slash piles were used by a single individual in our study, demonstrating their potential benefit for martens. Raphael and Jones (1997) found a strong seasonal pattern in the use of slash piles, with most use occurring during the snow-free period of the year. They hypothesized that martens discontinued use of slash piles in winter due to their limited thermoregulatory benefits compared to the solid boles of large diameter snags and logs or subnivean locations. Our data suggest relatively limited use of slash piles, thus managers should place a higher priority on retaining natural habitat features (e.g., large diameter snags, trees, logs) that can provide more reliable year-round resting resources.

All resting sites had dense shrub cover, including resting sites in serpentine and non-serpentine habitats. This agrees with the conclusions of habitat selection analyses conducted at the stand and home range level, in this same study area (Slauson et al. 2007). Importantly, the plant species dominating the shrub layers in these sites are shade tolerant, long-lived, mast-producing ericaceous species (e.g., *Gaultheria shallon, Vaccinium ovatum, V. californica, Rhododendron macrophyllum*) and shrub oaks (*Quercus vaccinifolia, Lithorcarpus densiflora echinoides*). They do not include, for example, the more familiar shade intolerant and short-lived disturbance-associated species of shrubs that can occur in northwestern California forests (e.g., *Ceanothus* sp.; Jimerson et al. 1996, Mahony 1999, Sawyer et al. 2000). Dense stands of mature, shade tolerant, shrubs provide refuge from predators, cover for prey, mast (e.g., berries and acorns) consumed by martens and their prey, and may also deter larger-bodied competitors by limiting their foraging abilities in such structurally complex habitats. Shrubs also create, or contribute to the formation of, some resting locations and resting structures and likely increase the suitability of these features. In other studies, martens have used shrub cover as resting locations (Martin 1987), foraging locations (Buskirk and McDonald 1984), and as overhead cover following disturbances from fire (Magoun and Vernam 1986, Paragi et al. 1996) and spruce budworm defoliation (Chapin et al. 1998).

Martens were more difficult to track to resting locations in serpentine habitats than in non-serpentine habitats. While dense shrub cover was a feature in both serpentine and non-serpentine habitats, making quiet approach difficult, we were less successful at pinpointing locations of martens resting in the serpentine habitats. Upon searching the area were martens were resting prior to becoming active and leaving, only rock and ground structures were found to be present. We believe that this may be due to the fact that martens in serpentine habitats were resting in more exposed locations (e.g., ground and rock-associated sites) and were better able to detect our approach in such resting locations, and/or they were more wary when resting in these types of structures. Thus, we believe the actual number of ground and rock-based resting structures was higher than we were able to quantify in serpentine locations. Rock and shrub resting structures have been rarely used by martens in other regions, only 4% of all resting structures reported (n = 788) in 13 studies were of these structure types (Shumacher 1999). The use of rock and shrub resting structures may be a unique feature of the biology of martens in coastal forests with serpentine intrusions.

Non-serpentine forest habitats dominate the historical range of the Humboldt marten in coastal northwestern California and 95% of the resting structures we found in these forests were in large live or dead woody structures. These large woody structures were located predominately in the stands classified as old growth. That resting structures are most common in these stands is consistent with the finding, from stand and home range-scale research, that martens disproportionately use old growth stands and the largest patches of old growth and late-mature forest (Slauson et al. 2007). The late-mature and old-growth developmental stages in the tanoak and Douglas-fir vegetation types have the highest mean densities of large diameter (>80 cm) snags and live trees relative to all other developmental stages (Jimerson et al. 1996) and, thus, should provide abundant resting resources. In serpentine-influenced habitats, marten resting structures occur in stands characterized as earlier developmental stages, likely because martens use rock and shrub resting structures when large trees are uncommon.

The resting locations found in this study were from observations made in the late summer, when temperatures are high and in the early fall when temperatures are dropping, but wet and cold conditions have not yet set in. We were unable to monitor martens into the winter rainy season, when conditions may require that martens select the driest and most thermally protected locations. Given that martens rested in cavities or chambers during the few rainy days that occurred during our study, we expect that use of cavity and chamber resting locations would increase during winter, similar to the results of work in the Oregon Cascades (Bull and Heater 2000).

Most resting structures required more than a century to develop. Given this and the competing commercial value of large trees, it is critical for managers to protect and retain structures that are currently suitable. Planning for the next cohort of resting structures must take into account the time and ecological processes involved in their creation. Furthermore, because of the unpredictable timing, intensity, and location of some key disturbance processes (e.g., wind throw), management strategies for the recruitment of suitable resting structures will need to include > 1 candidate tree to produce each future suitable resting structure. In areas where all large trees and snags have been removed, the creation of other types of potential resting structures (e.g., logs with chambers or cavities, slash piles, rock piles) may accelerate the occupation of these areas by martens.

Future studies of Humboldt martens should include resting habitat conditions used by marten during winter and spring and apply formal resource selection analysis (i.e., Manly et al. 2002). Managers can use the information from this study to guide the maintenance, recruitment, and restoration of suitable resting habitat in the historical range of the Humboldt marten. Such efforts, in conjunction with maintenance and restoration of the key stand and home range habitat characteristics described by Slauson et al. (2007), can be the backbone of a habitat conservation and management strategy for the only remnant population of the Humboldt marten.

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